

Reconstituted Earthquake Ground Motion at Anchorage

ABSTRACT: To aid analysis of the dynamic response of structures to the Alaska earthquake, a simulated accelerogram of the ground motion at Anchorage was constructed by combining information from a variety of secondary observations of the motion and its effects with knowledge of general earthquake ground motions. A maximum acceleration of approximately 15 percent of gravity is indicated. The strong ground shaking lasted for about 1 minute and was followed by approximately 3 minutes of lesser shaking.

The lack of any record of ground motion in the region of destructive shaking during the Alaska earthquake makes it difficult to evaluate precisely the engineering significance of much of the damage. The severity of the damage is a function of the character of the ground shaking and the physical properties of the structures concerned. Usually, the pertinent physical properties that a damaged structure had before the earthquake are not well known; therefore, analyses of the dynamic response of the structure to the recorded ground motion must reconcile the observed damage with the estimated properties of the structure. If ground motions are not recorded during the earthquake, such analyses are often made by using ground motions recorded during other earthquakes. In the case of the 1964 Alaska earthquake ($M=8.4$), however, the ground motion had certain special characteristics, such as duration of shaking, that differed from those of ground motions recorded in other earthquakes of lesser magnitudes. These differences make it difficult to perform appropriate analyses in those situations where these special characteristics are significant. The difficulty is especially serious for the landslides, where the cumulative effect of the ground shaking over the total duration is important. As accurate as possible an estimate of the nature of the ground shaking is therefore of considerable value in improving the results of dynamic analyses by providing more realistic excitation. Information is available about the ground shaking in Anchorage that can be combined with the knowledge of earthquake ground motions, in general, to construct an accelerogram that incorporates the major features of the ground shaking during the earthquake. This reconstituted ground motion can then be used in engineering analyses of the responses of soils or structures.

GENERAL PROPERTIES OF GROUND MOTIONS

It is well known from past recordings of earthquake ground motions that the free-field surface acceleration (horizontal)

is a transient random function that has an initial rise time, then a phase of strong shaking, followed by a gradual decay of the amplitude of motion. The duration of shaking is a function of the magnitude of the earthquake and the distance from the causative fault. Ground accelerations of large earthquakes in the United States that were recorded close to the causative fault, on firm ground, exhibit spectral characteristics that correspond approximately to white noise over the frequency range from 0.1 to 3.0 cycles per second (cps). The frequency content of ground motion can be influenced by such factors as the distance from the causative fault, which attenuates the higher frequency components more strongly than the low frequencies; the source mechanism, which can affect both the high frequency components and the low frequency components; and the wave speeds in the local soils, especially if the upper soil layer is extremely soft. The foregoing facts, inferred from recorded shocks, permit the construction of mathematical models of earthquake motion and the generation of accelerograms that simulate recorded motions.

SPECIFIC PROPERTIES OF ANCHORAGE GROUND MOTION

Because the specific properties of the ground motion at Anchorage are discussed by Hudson and Cloud (1973, this volume), only a summary of the pertinent features will be given here. The most important information for our purposes was recorded by Mr. Robert A. Pate on a tape recorder that he was using to dictate a letter at the time of the earthquake. The tape, with added narration, was reproduced by Mr. Pate on a 7-in. 33 1/3-rpm commercial phonograph record, "Earthquake—Alaska." We listened to the original tape, which is in the possession of Mr. Pate, to verify that the record was a true duplication without excisions or inserts. The noise of furniture rattling, house creaking, and so forth, together with Mr. Pate's comments, permit the time history of the intensity of shaking to be sketched as shown in Figure 1. The initial strong phase of shaking built up to a maximum at 20 seconds from the beginning and decreased to a relatively low value at 36 seconds. The second phase of strong shaking built up to a maximum at 53 seconds, which is slightly less intense than the initial maximum. The second phase decreased to a minimum at 66 seconds, followed by a slight increase, and then by a gradual decrease. After the first 120 seconds of ground shaking, the intensity decreased, until at 220 seconds when Mr. Pate had to pay careful attention to feel that the house was "still shaking a little." This remark indicates that the ground shaking had attenuated almost to the limit of perceptibility at 4 minutes after the initial motion. Figure 1

gives an accurate description of the times of maximum and minimum intensities and shows the estimated amplitude of the intensity as a function of time.

In Anchorage, the damage to one- and two-story buildings was not great, indicating that the higher-frequency components of ground shaking (approximately 3–10 cps) were relatively attenuated. This is consistent with Anchorage being 80 mi from the epicenter and somewhat closer to the nearest portion of the slipped fault. The Tehachapi, California, earthquake of July 21, 1952, was approximately 80 mi from the center of Los Angeles, and both the building damage and the recorded ground accelerations in Los Angeles indicated a relative attenuation of higher-frequency components. On the basis of the Tehachapi earthquake and other recorded shocks, it is estimated that the maximum acceleration at a distance of 80 mi from the causative fault of a very large earthquake would be approximately 10 percent of gravity and, at 60 mi, approximately 15 percent of gravity. The observed damage at Anchorage suggests that 15 percent of gravity is a reasonable estimate of the maximum acceleration in that city.

The damage to structures that had natural periods of vibration of about 1 second, together with observations of the amplitudes of vibration of hanging pictures and other oscillating systems, indicate that response spectrum values for periods near 1 second were similar to those of the 1952 Taft, California, accelerogram and somewhat less than those of the 1940 El Centro, California, accelerograms.

From previous earthquake motions, the maximum transient ground displacement at Anchorage was estimated to be on the order of 1 ft.

The spectrum of an aftershock recorded at Anchorage (Hudson and Cloud, 1973, this volume) does not indicate any marked influence of the local soils such as would be expected of a very soft upper layer of soil, as, for example, in Mexico City.

RECONSTITUTION OF THE GROUND ACCELERATION

The simulated ground acceleration at Anchorage was constructed in the following manner:

A pair of 2-minute-long samples of a stationary random process was used as a basis. The frequency components of this motion correspond to those of typical large United States shocks (Housner and Jennings, 1964).

The high-frequency components of one 2-minute-long segment were filtered on the digital computer by effectively passing the acceleration through an oscillator that had a natural period of 0.8 seconds and a damping of 70 percent

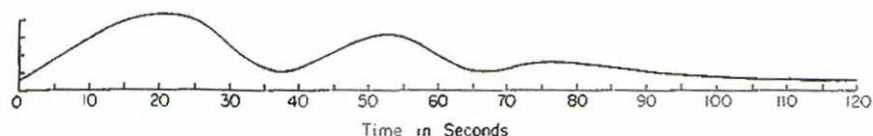


FIGURE 1 Shaping function for the amplitude of ground acceleration.

of critical. This procedure shaped the high-frequency end of the spectrum to correspond to ground motion at approximately 60 mi from the causative fault.

The acceleration was passed through a low-frequency filter with period of 10 seconds and 70 percent damping to control the maximum amplitude of the displacement obtained by double integration of the acceleration. The resulting filtered motion was shaped by multiplying it by the amplitude function shown in Figure 1; this procedure produced the 2 minutes of motion shown in Figure 2. The accelerogram was scaled so that the pseudo-velocity response spectrum had peak values, for 1 percent damping, of approximately 3 fps, as shown in Figure 3.

The second 2-minute-long segment of random function was passed through a high-frequency filter whose natural period was 1.5 seconds and whose damping was 70 percent of critical. This accounted for the fact that these motions had traveled greater distances. It was passed through the same long-period filter and was shaped by multiplying by an amplitude function that decreased linearly from the 120-second value in Figure 1 to one fourth of that value at 240 seconds.

The resulting 4-minute-long accelerogram is shown in Figure 4. The peak acceleration, which occurs near 18 seconds, is 14 percent of gravity. The maximum acceleration near the end of the 240 seconds of motion decreases to ap-

proximately 0.5 percent of gravity, but such motion would still be perceptible. The maximum acceleration of 14 percent of gravity is relatively small compared with the 33 percent of gravity recorded during the 1940 El Centro shock ($M=7.1$), which is a reflection of the attenuation of the short-period motion at Anchorage. For periods longer than approximately 0.5 second, the motion is almost as intense as the El Centro motion. The integrated velocity and displacement are shown in Figures 5 and 6.

USE OF THE RECONSTITUTED GROUND MOTION

It is envisioned that the accelerogram will be useful to engineers wishing to estimate the response of structures to the Alaska earthquake. Punch-card decks, or printouts, for the 240-second-long accelerogram in Figure 4, digitized at intervals of one fortieth of a second, are available for such studies. It is our opinion that the actual acceleration at Anchorage could not have differed markedly from that shown in Figure 4 in those characteristics significant to structural vibrations. In a statistical sense, however, the actual details of acceleration, velocity, and displacement shown in Figures 4, 5, and 6 are not significant; other accelerograms, constructed in exactly the same way from

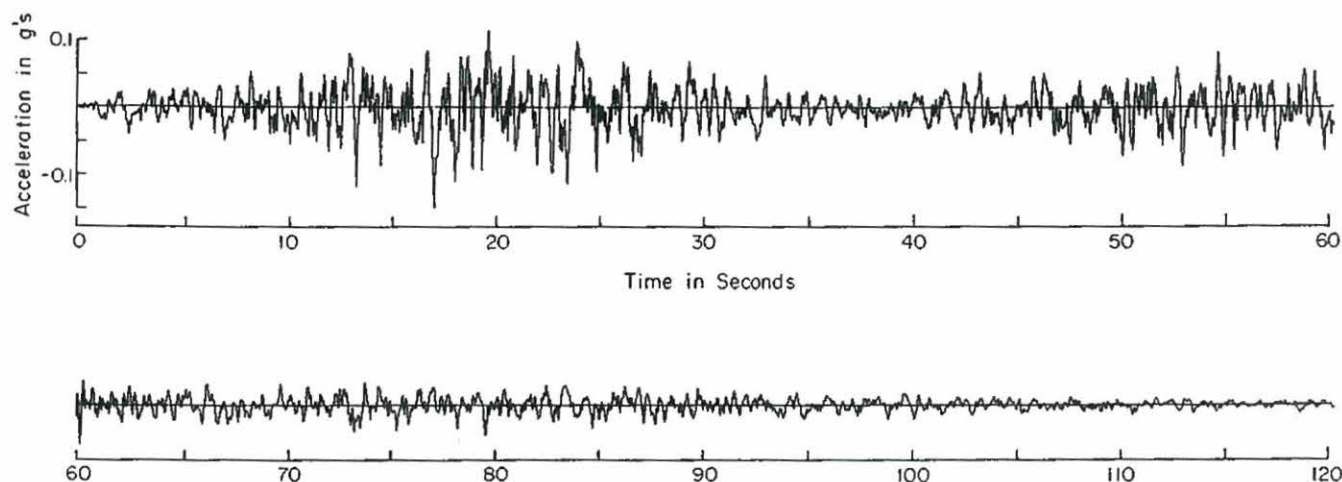


FIGURE 2 Simulated horizontal ground acceleration for the first 120 seconds of ground shaking at Anchorage, Alaska, during the earthquake.

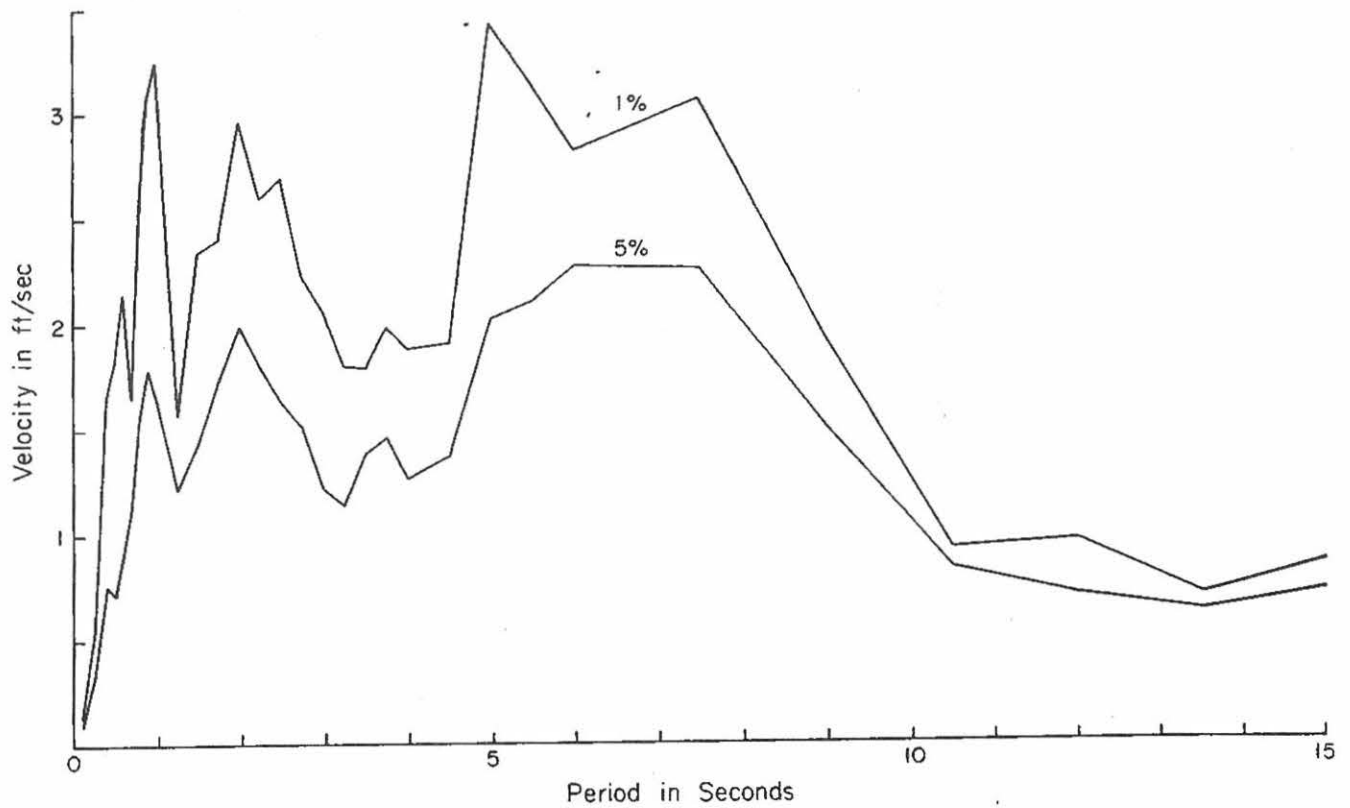


FIGURE 3 Pseudo-velocity response spectrum for the acceleration shown in Figure 2.

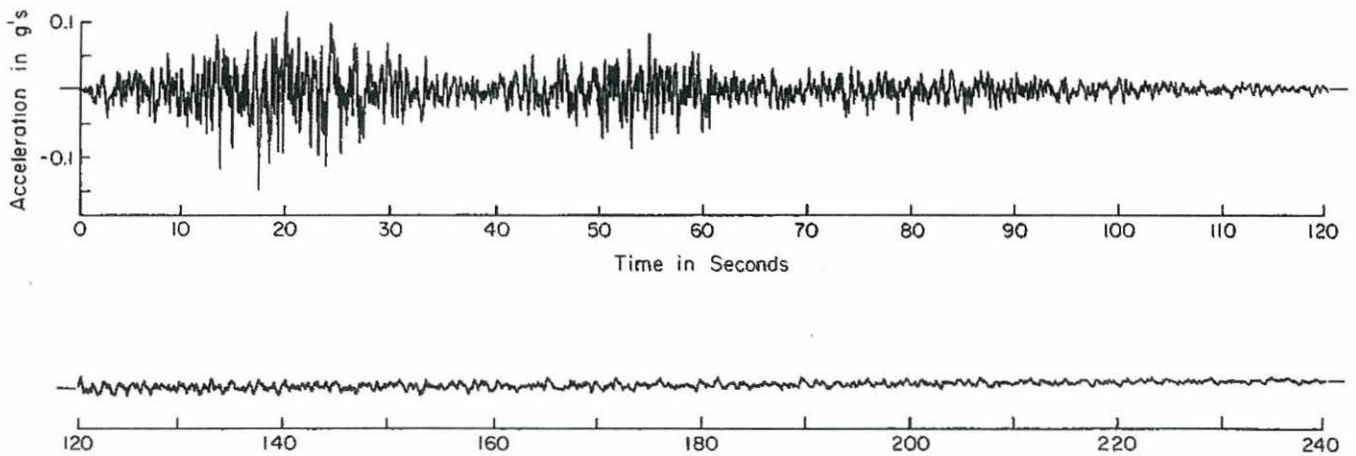


FIGURE 4 Simulated horizontal ground acceleration for 240 seconds of ground shaking at Anchorage, Alaska, during the earthquake.

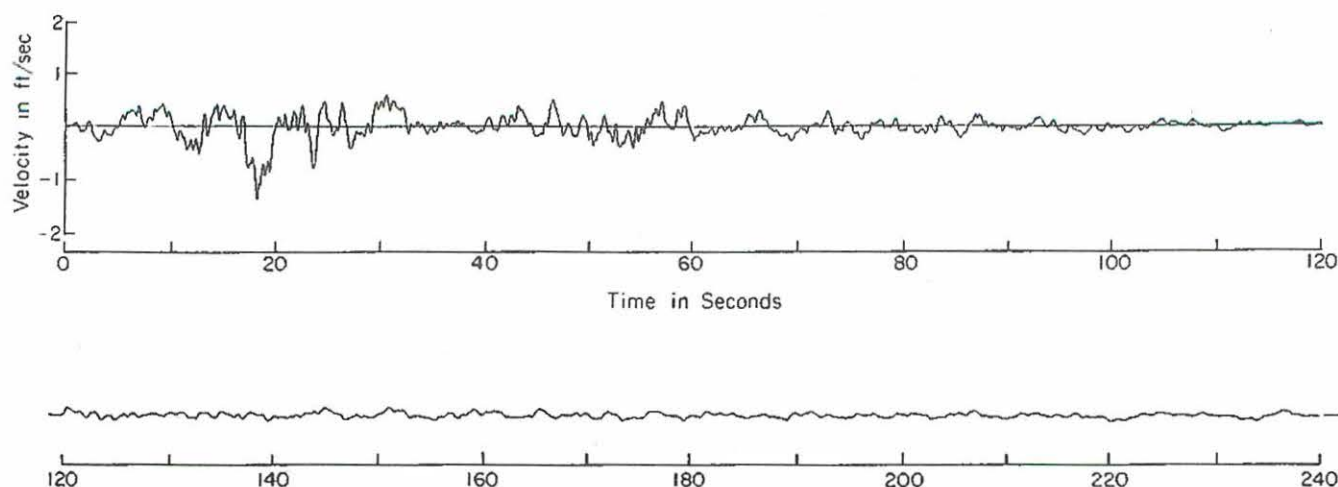


FIGURE 5 Integrated velocity of the acceleration shown in Figure 4.

different samples of the steady-state random function, would show different details and would produce statistical variations in response calculations.

SUMMARY

On the basis of a variety of facts known about the ground shaking at Anchorage, together with a knowledge of past recorded earthquake ground motions, a random function was generated that is judged to be a good estimate of the ground motion at Anchorage during the earthquake. The total duration of perceptible ground shaking is approximately 240 seconds. The strong shaking occurred during two intervals. The first and strongest shaking, with a peak acceleration of 14 percent of gravity and a duration of approximately 30 seconds, is followed by a 20-second segment

with a peak acceleration of 9 percent of gravity. Presumably these periods of shaking were caused by two major events on the causative fault. The strong shaking occurs during the first minute of motion. The last 3 minutes of motion are less strong and the acceleration decreases to a peak value of about 0.5 percent of gravity at the end.

The nature of the accelerations is such that higher frequencies (> 2 cps) are attenuated, accounting for the fact that the peak acceleration of 14 percent of gravity is not large. For lower frequencies (< 1.3 cps), the shaking is strong, comparable in intensity to the Taft, California, record of July 21, 1952, and almost as strong as the El Centro, California, record of May 18, 1940. The 60-second duration of relatively strong motion, together with the following 180 seconds of weaker motion, would, of course, make the shaking more destructive than a short earthquake of similar intensity.

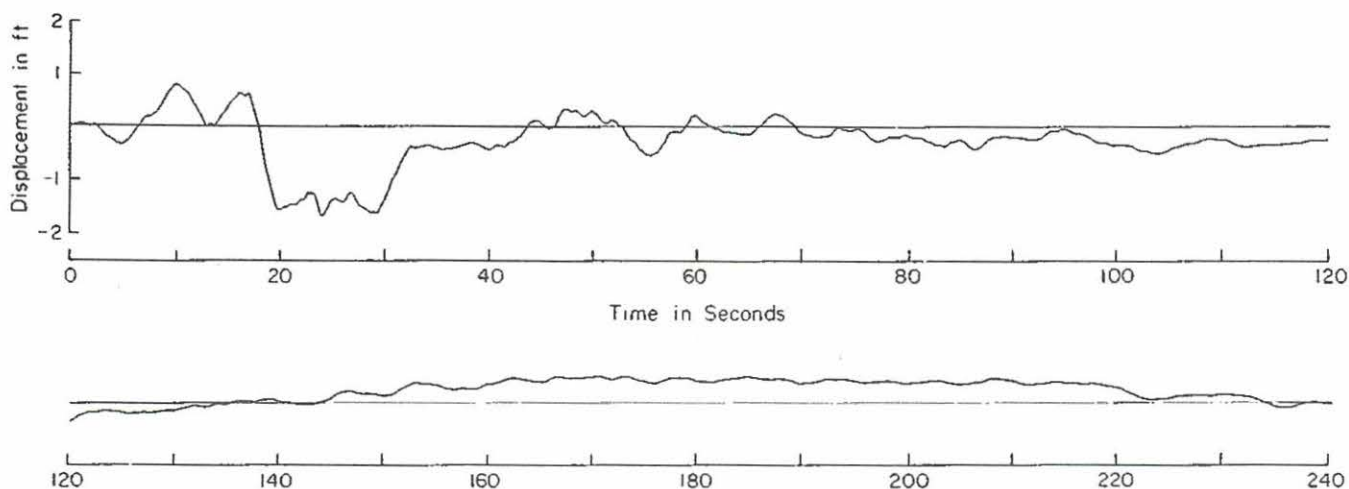


FIGURE 6 Integrated displacement of the velocity shown in Figure 5.

The reconstituted ground motion can be used to analyze the responses of structures and soils in the Anchorage area during the earthquake.

ACKNOWLEDGMENTS

We are indebted to N. C. Tsai and J. R. Born for carrying out the digital computations and to the National Science Foundation for contributing to the support of this investigation.

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